

# **LIGHT EMITTING DIODE DEVICE AND MANUFACTURING METHOD**

## **BACKGROUND OF THE INVENTION**

### **1. Field of the Invention:**

5       The present invention relates to a light-emitting diode device and method of manufacturing the same, and more particularly to the light emitting diode (LED) device includes a light-transmission conductive layer with high transparency and a patterned transparent conductive layers. Further, the LED device of present invention has the light-transmission conductive layer with high transparency and a 10 patterned transparent conductive layers so as to improve the transmission efficiency, ohmic conductivity and light brightness.

### **2. Description of Related Art:**

15      The conventional light emitting diode (LED) device, especially InGaN LED device, has the problem of light intensity degradation. As shown in Figure 1a, the conventional InGaN LED element an n-type GaN layer 21, an InGaN active layer 22, a transparent conductive layer 24, and a p-type GaN layer 230 which are stacked sequentially in layers on the top face of a sapphire substrate 30. The substrate 10 of conventional light emitting diode device is formed on the bottom of light emitting 20 diode device. The semiconductor layer 20 has an n-type semiconductor layer 21, an active layer 22 and a p-type semiconductor layer 23, wherein the active layer 22

grown between the n-type semiconductor layer 21 and the p-type semiconductor layer 23, an n-pad 210 on the n-type semiconductor layer and at least a p-pad 230 on the p-type semiconductor layer 23 ; a transparent conductive layer 24 is formed above the p-type semiconductor layer 23.

5 Referring to figure 1a and 1b, the conventional light emitting diode device has the problems of low brightness and light intensity degradation. The reason for the low brightness is the low transparency of transparent conductive layer of conventional LED device. The transparency of transparent conductive layer of conventional LED device is only 50% light transmission efficiency.

10 Even though generally transparent conductive layer of LED device is implemented with high transparency materials for increasing the light transmission efficiency, the LED device only reaches 70% light transmission efficiency . Such low transparency of transparent conductive layer still limit the light brightness of the LED device.

15 In response to the shortcomings and drawbacks of conventional LED device designs, several alternative approaches have been proposed in order to improve the light transmission efficiency of transparent conductive layer and thus the brightness of LED device produced therefrom.

The present invention provides a metal-oxide layer mixed with transparent 20 conductive layer to increase transmission efficiency of transparent conductive layer.

## **SUMMARY OF THE INVENTION**

The primary objective of the present invention is to provide a light emitting diode device, more particularly a light emitting diode device having a light-transmission conductive layer with high transparency and a patterned 5 transparent conductive layer.

Another objective of the present invention is to provide a manufacturing method of light emitting diode, more particularly a method of manufacturing high brightness light emitting diode device with a light-transmission conductive layer with high transparency and a patterned transparent conductive layer.

10 Furthermore, the third objective of the present invention is to provide a light emitting diode device with a patterned transparent conductive layer and a patterned reflection layer. As above described, the patterned transparent conductive layer is able to improve the illumination of light emitting, and the patterned reflection layer reflects the light absorbed by the patterned transparent conductive layer.

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## **BRIEF DESCRIPTION OF DRAWINGS**

Figure 1a illustrates a simplified schematic diagram of a conventional light emitting diode device;

20 Figure 1b illustrates top view of conventional light emitting diode device;

Figure 2a illustrates a simplified schematic diagram of the present invention of light emitting diode device;

Figure 2b illustrates a top view of the present invention of light emitting diode device;

Figure 3a illustrates one of embodiment of patterned transparent conductive layer of light emitting diode device of present invention;

5       Figure 3b illustrates one of embodiment of patterned transparent conductive layer of light emitting diode device of present invention;

Figure 3c illustrates one of embodiment of patterned transparent conductive layer of light emitting diode device of present invention;

10      Figure 4 illustrates the relationship between a transparency of patterned transparent conductive layers divided to transparency of light-transmission conductive layer and patterned transparent conductive layers area in present invention ; and

15      Figure 5 illustrates a simplified schematic diagram of another embodiment of light emitting diode device of the present invention.

## **DETAILED DESCRIPTION OF PREFERRED EMBODIMENT**

The present invention provides a light emitting diode device having a light-transmission conductive layer with high transparency and a patterned transparent conductive layer for increasing light brightness. Referring to Fig. 2a, the LED of present invention, for example an InGaN LED device, comprising a sapphire substrate 10 on the bottom of the light emitting diode device; a

semiconductor layer 30 is formed above the substrate 10 including an n-type semiconductor 31, an active layer 32 and a p-type semiconductor layers 33, wherein the active layer 32 is formed between the n-type semiconductor layer 32 and p-type semiconductor layer 33; a patterned transparent conductive layer 40 is formed on 5 the p-type semiconductor layers 33 and filled with a light-transmission conductive layer 50 so as to increase transmission effectively of the high brightness light emitting diode device; wherein the n-type semiconductor is an N-GaN layer, the p-type semiconductor layer is a P-GaN layer, the active layer is an InGaN/GaN multiple quantum well structure, and the patterned transparent layer is a 10 metal-oxide which is made with at least one of metals including Ni, Au, Cr, Ir, Pt, Ag, Ru and Be etc. composed with oxide. The light-transmission layer with high transparency is an oxide layer selected from the group consisting of indium tin oxide (ITO), indium oxide, tin oxide, zinc oxide, and magnesium oxide. Further, the present invention provides a method of manufacturing the high brightness LED 15 device more particularly to the light emitting diode device with a light-transmission conductive layer with high transparency and a patterned transparent conductive layer manufactured method.

In accordance with the present invention to manufacture the LED device, for example, manufacturing an InGaN LED device to high brightness is the 20 embodiment of present invention. The InGaN LED device was grown on a C-plane Sapphire substrate 10, the pure  $\text{Al}_2\text{O}_3$  material. The thickness of the Sapphire substrate is about 300 $\mu\text{m}$ . Next, a semiconductor layers 30 was formed on the

substrate 10 by MOCVD. Above the semiconductor layer, Si ions are implemented in the n-type GaN layer to 3.5 $\mu$ m thickness, an active layer 32 is formed with multiple quantum well of InGaN/GaN and then Mg ions are implemented in a p-type GaN. After forming the layers of above description, parts of p-type GaN are  
5 etched to expose the n-type GaN as an n-GaN layer 31. Forming a p-type and an n-type ohmic contact layers, there are a plural of layers formed above the semiconductor layers. An n-type ohmic contact layer is formed with reactive ion etching technique. Part of semiconductor layers is removed till n-GaN layer. Ti and Al is deposited as n-type contact layer and an n-pad 210. Hereinafter, a transparent  
10 conductive layers are made of NiO and Au; then using Ti and Al ions deposited on to form a p-type ohmic contact layer and a p-pad 230.

In order to increasing brightness, the TCL of LED device with low transparency need to be replaced, so the present invention provides a light-transmission conductive layer with ITO, indium-tin-oxide, materials to  
15 increase the transparency of LED device. On the other hand, the ITO of conductive layer made the LED device with low ohm property. So the present invention of TCL of LED device is divided to a plural of region and arranged in matrix-lines called a patterned transparent conductive layer 40. On the patterned transparent conductive layer, a light-transmission conductive layer 50 is overlaid.

20 Referring to figure 2b showing the top view of embodiment of present invention, the LED device includes a light-transmission conductive layer and a patterned transparent conductive layer. The light-transmission conductive layer 50

with high transparency overlays the patterned transparent conductive layer 40. In figure 3a,3b,3c shows the shape of patterned transparent conductive layer is net-shaped, spot-shaped, or any other successive shape with hollow out. The hollow is filled by the light-transmission conductive layer 50 which is an oxide layer selected from the group consisting of indium tin oxide (ITO), indium oxide, tin oxide, indium lead oxide, lead oxide, antimony tin oxide, antimony oxide, antimony zinc oxide, cadmium tin oxide, cadmium oxide, zinc oxide, and magnesium oxide in present invention.

Further, in the above embodiment, the high brightness LED device includes a patterned transparent conductive layer 40 and a light-transmission conductive layer. The method of manufacturing LED device comprising: forming a substrate 10 on the bottom of the high brightness light emitting diode device; forming a semiconductor layer 30 above the substrate 10 includes an n-type semiconductor, an active layer and a p-type semiconductor layers, wherein the active layer formed between the n-type semiconductor layer and p-type semiconductor layer; forming a patterned transparent conductive layer 40 formed on the p-type semiconductor layers ; and forming a high transparency conductive layer 50 formed overlay the matrix-lines transparent conductive layer.

Assuming the external quantum efficiency of transparent conductive layer of LED device is equal to the LED device with a matrix-lines TCL and an ITO layer with high transparency. The equation is:

$$A T_T = (A-a) T_I$$

where  $a$  is the spreading area of patterned transparent conductive layer;  $A$  is the area of light emitting diode ;  $T_T$  is the transparency of transparent conductive layer;  $T_I$  is the transparency of light-transmission conductive layer.

5 Arranging above equation,  $a = (1 - T_T/T_I)A$ .

So if  $a < (1 - T_T/T_I)A$  is true, the light transmission efficiency of LED would be increased.

10 Referring to figure 4, shows the relationship between the transparency of patterned transparent conductive layers divided to the transparency of light-transmission conductive layer and the area of patterned transparent conductive layers in present invention. for example,  $T_T$  is 50%,  $T_I$  is 98%,  $T_T/T_I = 1.96$  and the area of the LED device of present invention is  $300\mu\text{m} \times 300\mu\text{m}$ , while the area of 15 patterned transparent conductive layer is smaller than  $44082\mu\text{m}^2$ , the brightness of LED device can be increased.

Referring to figure 5, a simplified schematic diagram of another embodiment of light emitting diode device of the present invention, the embodiment of high 20 brightness of LED device of present invention comprising: a sapphire substrate 10 on the bottom of the light emitting diode device; a semiconductor layer 30 is formed above the sapphire substrate 10 includes an n-type semiconductor 31 is

made of a GaN compound to an n-type GaN layer, an active layer 32 and a p-type semiconductor layer 33 is made of the GaN compound to a p-type GaN layer, wherein the active layer 32 is formed between the n-GaN layer 31 and the p-GaN layer 33; a patterned reflection layer 41 is formed on the p-GaN layers 33; a  
5 patterned transparent conductive layer 42 is formed on a patterned reflection layer 41; and a light-transmission conductive layer 50 is formed overlay a hybrid of the patterned transparent conductive layer 40 and the patterned reflection layer 41; wherein the patterned reflection layer 41 reflects light which is absorbed by the patterned transparent conductive layer 40 so as to increase illumination of the light  
10 emitting diode device.

The aforementioned are only exemplarity preferred embodiments of the present invention. The scope of the claims as to be stated below should be accorded to the broadest interpretation so as to encompass various modifications and similar  
15 arrangements made without violation of the basic principle and technology of the present invention.